418 Review of the Electrica[illegible]omm. Labo.
Vol. 27 No. 3/4 (1979-03/04)

[COMM]UNICATION LABORATORIES
VOLUME 27, NUMBERS 3-4, MARCH-APRIL, 1979

U.D.C. 621.396:654.16:69.057

Prefabricated Building System for Radio Relay Stations

E04H12/10

Tatsuo KUWAHARA, Akira MATSUDA, Yoshio KUSIHARA and *Tokinori NAGAO*

As radio relay stations are often constructed near the top of a mountain, it is difficult to obtain good building quality and performance and the work term is likely to be delayed if conventional construction methods are adopted. To resolve these problems, a prefabricated building system has been developed. In this system, structural frame is composed of steel components, external wall is precast concrete panel curtain wall, and radio antenna tower is put on the building. This system has merits of reducing time and manpower for field work, and obtaining good building performance, compared with conventional construction methods.

1 Introduction

Radio relay stations are frequently constructed on the top of mountains, so construction work is greatly influenced by the severe conditions due to the geography and weather conditions on the site. This requires the construction work to be performed in a very disadvantageous environment. Recently, in Japan, there is an extreme shortage in the number of construction engineers or construction workers, due to the tremendous amount of increase in construction requirements. It therefore becomes more difficult to gather site workers when the construction must be carried out on the top of a mountain. This may inevitably cause some delay in usual construction methods, particularly in constructing cast-in-place reinforced concrete structures. This also may cause some problems in obtaining good quality radio stations.

To overcome these problems, it is proposed to construct radio station by a prefabricated construction system.

In this report, it is considered that the present system is applicable all over the islands of Japan, except those areas in an extreme cold zone, heavy snow zone and permanent strong wind pressure zone. Two story radio stations and single story radio stations, both of which have been constructed with conventional construction system in NTT, were proposed to be constructed using the prefabricated system.

These prefabricated radio station are constructed with steel frames, while outer walls are made of precast concrete panel (hereafter abbreviated as P.C. panel). A steel antenna tower is mounted on the radio station building. Trial construction of prefabricated radio station building was carried out from 1977 to 1978. In August, 1978, the first trial prefabricated radio station was completed. (See Fig. 1.)

This report is concerned with design conditions, design philosophy, construction method and evaluation of the prefabricated radio station.

2 Design Conditions

2.1 Applicable Conditions

The applicable conditions for a prefabricated radio relay station are shown in Table 1. In the table, a part of the area where weather conditions are extremely severe is excluded in describing the applicable zones. The reason for this is that, if it is attempted to cover all of Japan, it would cause an excessive design from the view point of building performance in most areas. Thus, it would become

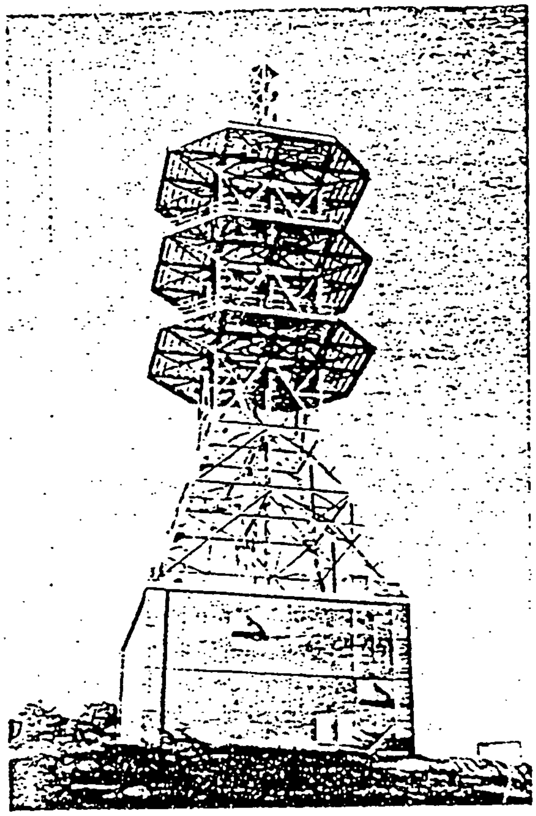


Fig.1 –Trial station building.

difficult to make an economic design. Howeve may be possible to apply this system to those a by modifying the present design, for instance, changing building compornent sizes.

The communication facilities to be installed, required equipment room area and the temperat and humidity control range are assummed to the same as for the present standard radio stati

As stated previously, since radio relay stati are frequently constructed on or near the top mountains, it becomes necessary to construct n roads in many cases. However, in some cases becomes impossible to construct the new ro due to geographical reasons or due to preservati of natural environments. Therefore, the desi was developed by presuming that helicopet could be used to transport the necessary constru tion materials, in addition to usual transporti methods using the roads.

2.2 Prefabricated Radio Station Utilization Aim

The following items were aimed at in utilizi prefabricated radio stations in terms of the effects and limits in prefabricated constructic engineering.

Table 1 APPLICATION

Item	Abstract
1. Territory	All parts of Japan, except for the following*: (1) Very cold area in Hokkaido: monthly average daily minimum temperature in January, under −20°C (2) Deep snow area: the snow load is over 1 ton (depth of snow, about 3 meters) (3) Area south of 30 degrees North latitude
2. Facilities to be accommodated	Same as the facilities accommodated in standardized microwave relay stations, two story (standard D4) and one story (standard S4) (unattended relay station)
3. Building materials transporting conditions	(1) If the site has a road, building materials can be transported by 4 ton trunk (2) If the site has no road, building materials can be airlifted by helicopter

* In these areas, radio relay stations are designed individually. However, this system is applicable if the size of building materials and the kind of insulation are modified.

(1) Shorten the eight month construction period, which is considered necessary for cast-in-place reinforced concrete construction, to six months, when building two story stations. This makes it possible to complete the radio station with antenna tower before the snow season if the construction work is begun in spring, when snow begins to melt, even in a heavy snow zone. This also leads to avoiding extending the construction period due to a necessary waiting period during the winter.

(2) Reduce the amount of construction man-power to 60% of the usual construction method by adopting the most simple site work methods as much as possible, considering the disadvantageous work conditions at the site.

(3) Reduce the amount of transportation to 65% of the usual method considering the severe conditions of transporting material to the site.

(4) Achieve sufficient building quality and performance.

(5) The construction cost target is set at an equal level of the usual cast-in-place rainforced concrete construction by ordering the construction work following a well programmed schedule. Approximately 40 radio stations are to be constructed in one year.

2.3 Main Radio Station Performance Requirements

Main performance requirements for the radio station are shown in Table 2. These requirements were determined by first considering communication facilities to be installed in the station, second the actual state of using the station, that is not usually occupied by any personnel.

(1) Earthquake resistance should be such that, during and after strong earthquakes with an intensity scale of class VI, the communication facilities would not break down although some degrading in communication functions would inevitably occur.

(2) Resistance against wind should be preserved such that dynamic wind pressure heads would not be lower than $120\sqrt[4]{H}$ and/or would be greater or equal to 300 kg/m², where H denotes the structure height in meters. These values were selected by considering the site conditions wherein the station would be constructed along the side of mountains where the strong wind pressure would act upon the structure.

(3) Fire resistance should be preserved, such that clearance of about 14 meters around the structure would be sufficient to prevent forest fires in areas surrounding the station. Furthermore, materials to be used as roof and outer wall should be chosen to have one hour fire resistance, in order to protect the equipment room, where communication facilities are installed, from forest fires.

(4) Outer wall thermal resistance should be preserved such that, for a 70% relative humidity, the inside wall surface would not sweat. This was derived by assuming thermal conditions wherein outer air temperature was −20°C, while inner air temperature was 20°C, this being the most critical thermal conditions.

(5) Watertightness should be preserved, such that, for 300 kg/m² maximum wind pressure,

Table 2. MAIN PERFORMANCE REQUIREMENTS

Item		Prefabrication System Performance Requirements	Conventional Standardized System Performance Requirements (Reference)
Earthquake Resistance (Structure)		Safe under earthquake intensity Scale VI	Safe under earthquake intensity Scale VI
Wind Pressure Resistance (Structure)		Safe under velocity pressure 300 kg/m²	Safe under velocity pressure 300 kg/m²
Fire Resistance (Outer wall)		Fire resistance time: 60 minutes	Fire resistance time: 120 minutes
Heat insulation	Outer wall	1.5 m²h°C/kcal	2.0 m²h°C/kcal
	Roof	2.0 m²h°C/kcal	1.8 m²h°C/kcal
Water tightness (Outer wall)		Water leakage doesn't occur under wind velocity 70 m/sec	—

water would not leak inside the wall, according to tests specified in JIS A1414.*

(6) Impact resistance of 28 kgm/sec should be preserved, so that the outer wall would not be damaged by flying objects, such as gravel and branches, during strong winds.

3 Basic Study

3.1 Combination of Radio Station Build and Steel Tower

A radio relay station must be provided w steel tower to support microwave antennas a station building, where communication equip is to be installed.

Present standard radio station buildings h steel tower erected on the radio station buil In utilizing this prefabricated system, the follo three types of prefabricated station buildings studied and compared with each other. (See Fi

* Japan Industrial Standard 1414. Method of test for resistance of structural components and panels for buildings.

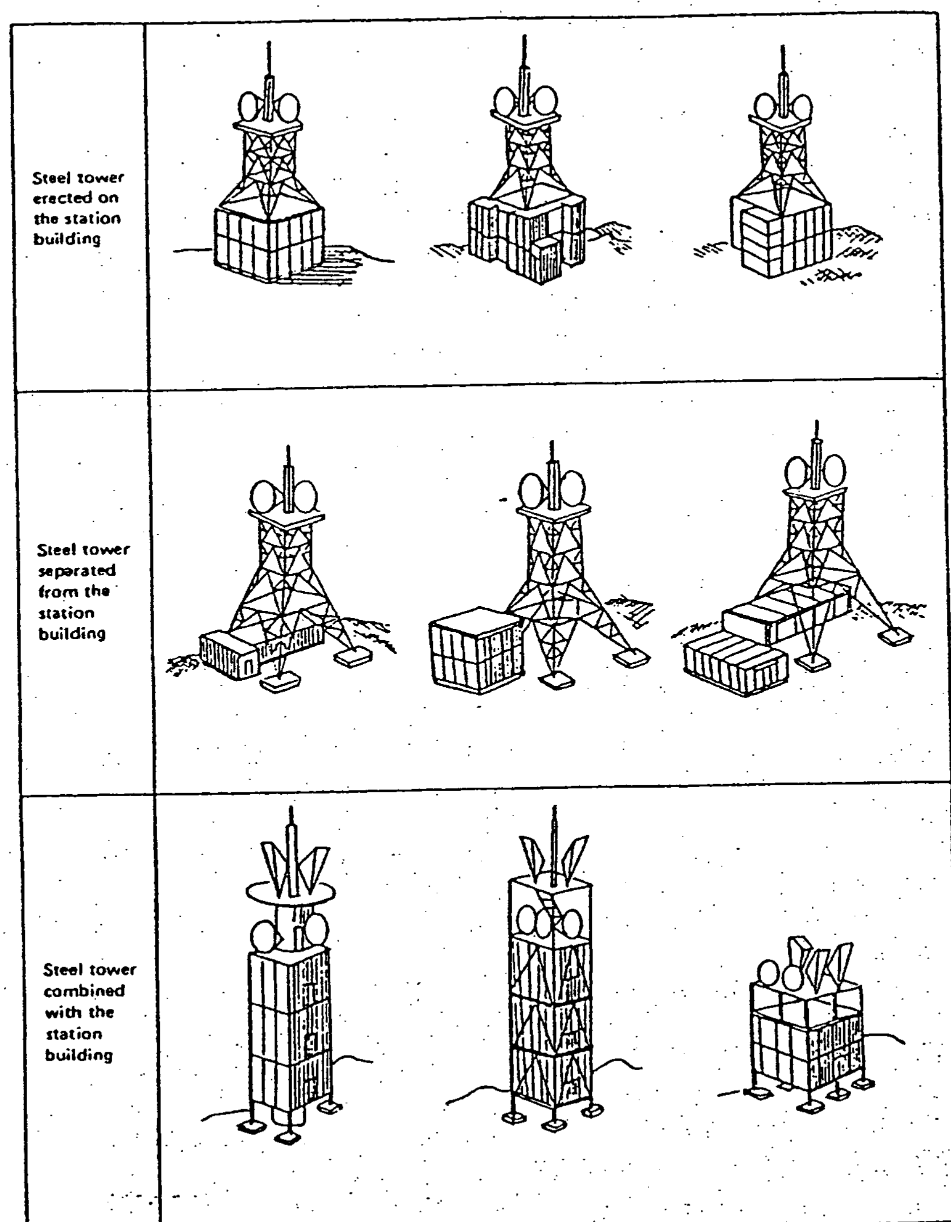


Fig.2–Station building and steel tower combinations.

(1) Steel tower erected on the station building
This type of combination furnishes freedom in combining and selecting the station building and steel tower, to a certain extent. Therefore, a large area construction site is not needed.

(2) Steel tower separated from the station building
This combination poses no restrictions in selecting the station building and steel tower, but it requires a larger area construction site. It is expensive to level a large site area on a mountain side or top. It is also possible that problems may arise due to the altering of mountaneous views. Therefore, this type is generally not suitable for the present purpose.

(3) Steel tower combined with station building
This combination has an advantage in giving an impressive appearance but it should also provide many combinations of steel towers and station building. Therefore , this category is not suitable for a standard.

It was decided that category (1) was the most suitable and practical for prefabrication.

3.2 Design Philosophy

Prefabricated station building design philosophy is as follows:

(1) For establishing a steel tower together with the station building, the station building layout should basically be located within the tower feet.

(2) A simple structural system should be employed to form a single structure composed of steel tower and station building.

(3) Since conventional communication facilities were used for the station building, the same dimensions in each part of the building are to be used. A 7 meter column span is chosen, considering the equipment layout, while clearance from the floor to the bottom of girders is 3.5 meters in the equipment room and 3.65 meters in the power room.

(4) Seven conventional standard steel towers were adopted for construction on the station building. Larger sizes of towers would be out of the applicable range.

4 Station Building Briefing

4.1 Structural System

To obtain earthquake resistance in the building, on which the steel towers are to be constructed, with heavy live loads on the station building, it was decided to select a steel frame structure, as shown in Fig. 3. Two kinds of materials to be used for the structural frame would be considered, steel structure and reinforced concrete structure. Since the component members are relatively light, and steel tower stresses can be smoothly transferred to the station building, it was decided to use a steel frame for the prefabricated station building. The steel structure has excellent capacity in combining two different structural components.

4.2 Radio Station Building Layout

A ventilation system has usually been used for equipment room cooling at radio relay stations. However, in this prefabricated station, an air conditioning system using air cooled small package air conditioners is used to save manpower during on the site work and also to increase temperature and humidity control. (Refer to Section 7.) Air-conditioners in the equipment room were arranged along the outer wall, in such a way that they would not cause any trouble in the communication facility layout, thus saving space in the fan room. This air conditioning system also saves space in the air chamber which is necessary for usual ventilation system to block out rain and snow, when inducing a great amount of outer air into the room.

This air conditioning system, therefore, makes it possible to reduce the floor areas of station buildings, so that the building layout plan would be placed within a basic 14 meter × 14 meter area between the steel tower legs. (Refer to Fig. 4.)

For a single story station building, preparatory room and toilet, which could not be placed within the tower legs, were constructed as a bearing wall structure using precast concrete panels. These rooms were separated from the fundamental space and were treated as attached space. (Refer to Fig. 5.)

5 Building Component Design

Each building component was designed based upon the main performance requirements (refer to Table 2), and also based upon the material transport conditions and ability to install component at the site. In this section, the space components are

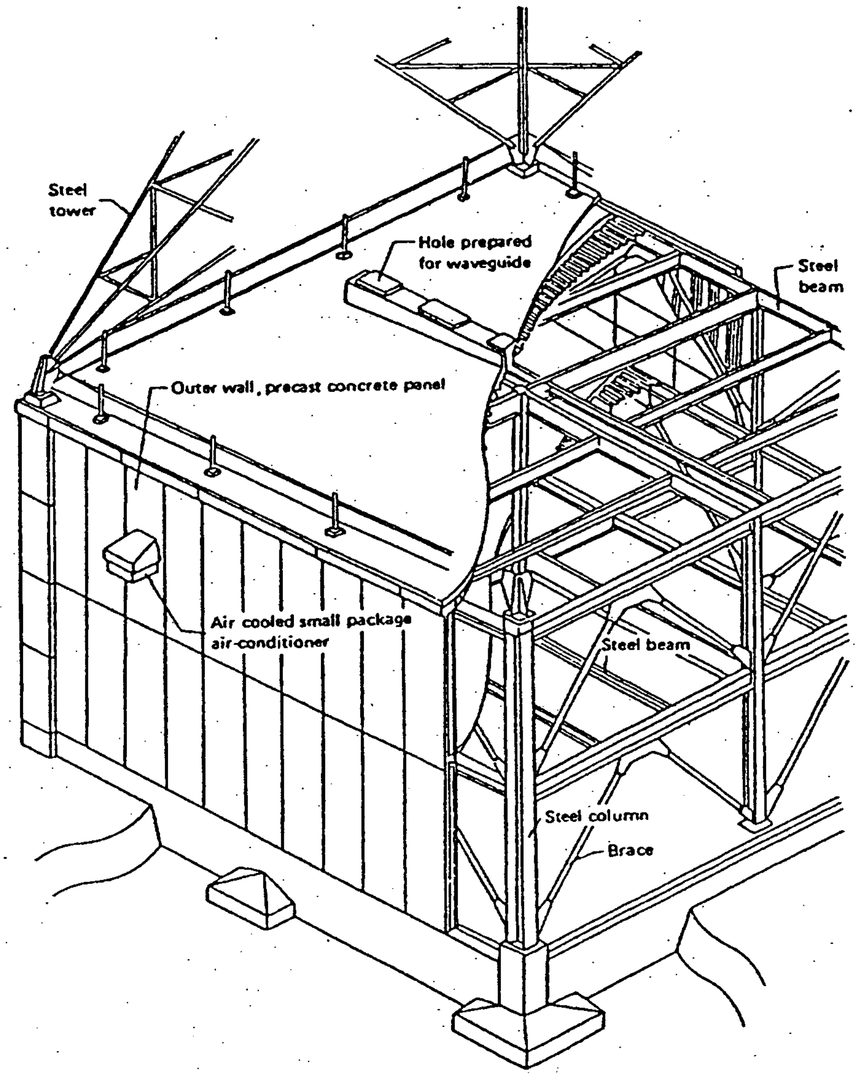


Fig.3–Concept presented by this system.

mainly discussed. Structural components are discussed in Section 6.

5.1 Transport Conditions and Hoist Work

5.1.1 Transport Conditions

Two different transport conditions were considered. The first condition is that the site has a road. The second condition is that there is no road. Different means of transporting materials would be selected, depending upon the transport condition. Each transport condition is shown in Table 3. When transporting building components and construction equipments, such as hoists, the site, these conditions should be satisfied.

5.1.2 Componet Weight

Component weight for this prefabricat system was determined according to the lift capacity of a heavy hoist to be transported to site. The heavy hoist work direction may be lin ed, depending upon the relative position of station building and the site, when installing cc ponents at the site. These relative positions radio relay stations built so far, are shown in Ta 4, in relation to the station building and the s

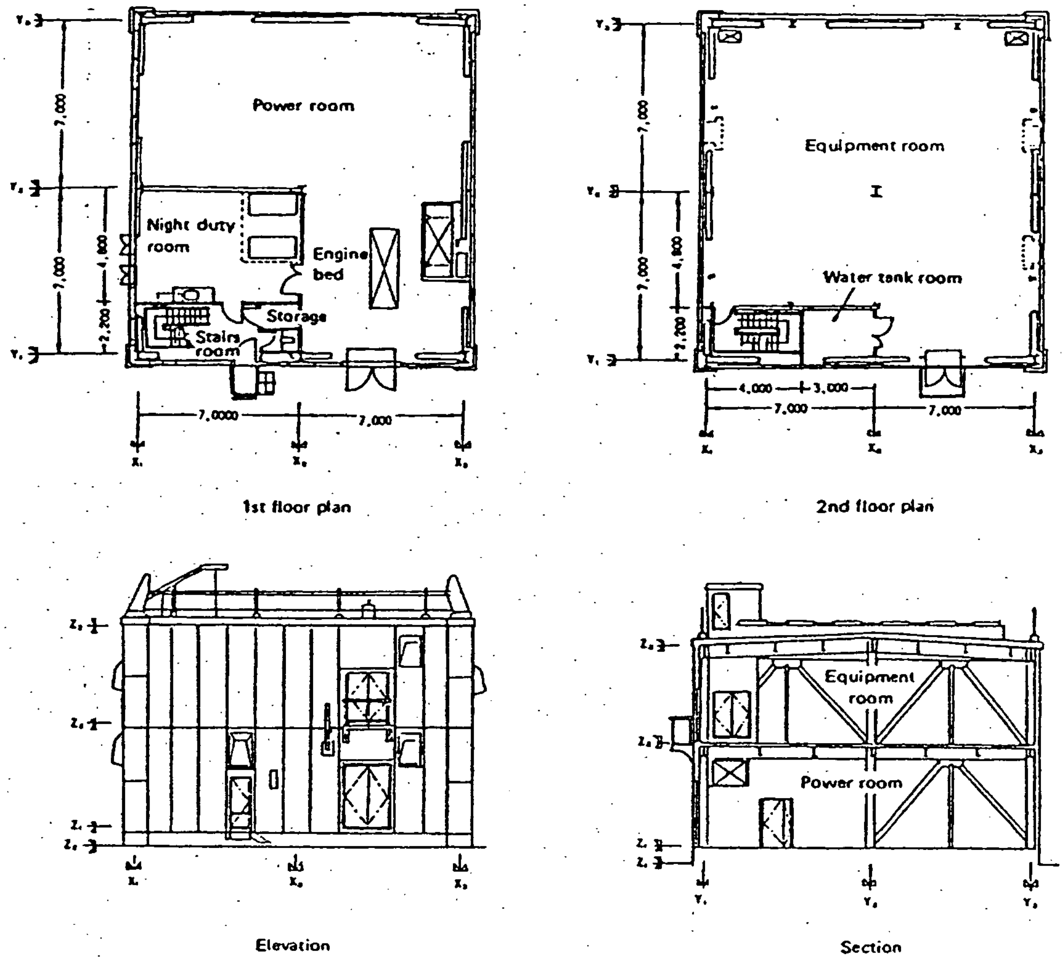


Fig.4–Two story radio relay station.

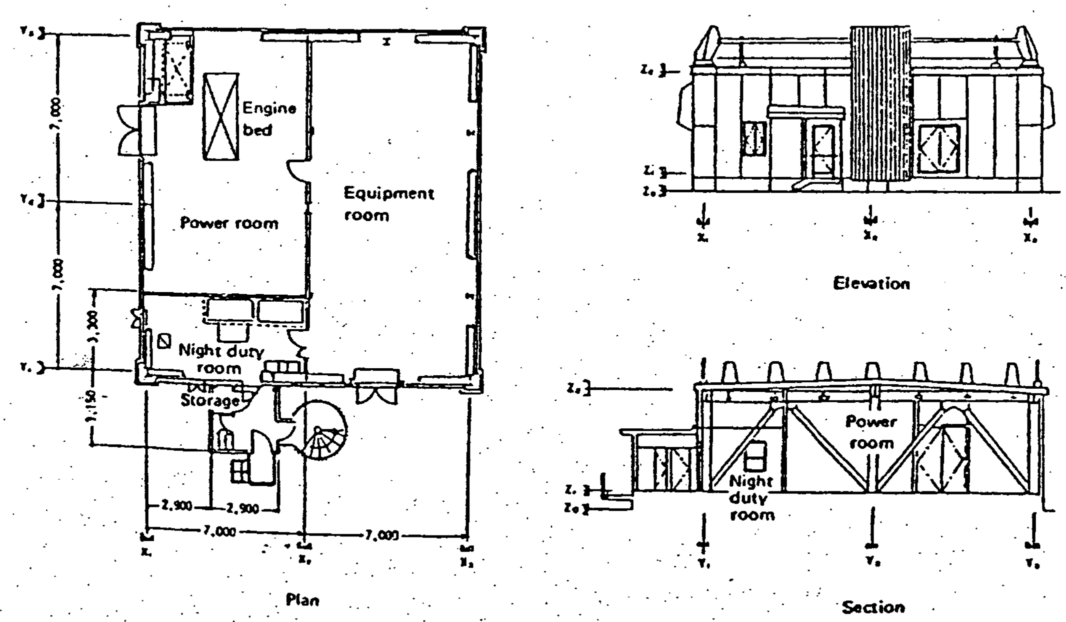
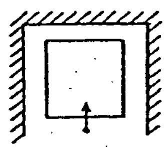
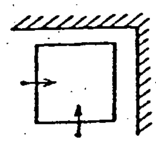
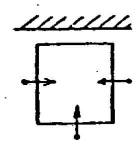
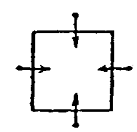


Fig.5–One story radio relay station.

Table 3 TRANSPORT CONDITIONS AND HOIST WORK MEANS

Transport Conditions	Transport Means	Transport Restriction	Hoisting Steel and Precast Concrete Panel	Note
Site has a road	4 ton truck	Maximum weight of truck with load: 10 tons Maximum size of load: 2.5 meters wide 12 meters long	Use 5 ton truck crane, with 2 ton jib crane.	This road is an exclusive NTT road.
Site has no road	Helicopter	Maximum load weight: 2.5 tons	Use 2 ton jib crane, with gin pole derrick	

Table 4 HOIST WORK DIRECTION, DEPENDING UPON RELATIVE STATION POSITION AND SITE

	Erection from one direction	Erection from two directions	Erection from three directions	Erection from four directions	Total
Hoist Work Conditions					Total
Number of constructions*	10	30	22	20	82

* From Facilities Hand-book edited by NTT, 1973

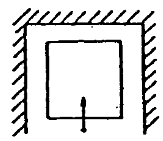
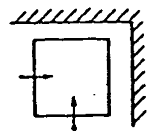
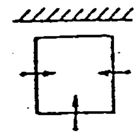
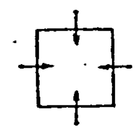
area. The table shows that, in 48% of the total station building construction, heavy hoist work was restricted to one direction or to two directions.

The most convenient method is to use a truck crane to hoist components into place on the site, taking into account the size of the station building and also the site conditions. Therefore, truck cranes were mainly used at the site to perform heavy hoist work. However jib cranes were also used in performing heavy hoist work, when the truck crane alone could not complete the work. Jib cranes and jin poles were also used to perform heavy hoist work during erection at the site, when materials were transported by helicopter, although the erection work may take much time.

Steel components may be hoisted into place under the condition that hoist work is restricted to one direction at the site. Erection may be done by retracting the cranes from the deep end of the site to perform hoist work. The maximum steel component weight for hoist work is 4 tons. heaviest single piece of steel components is proximately 4 tons. This equals the weight c corner column with no joint for constructin two story station building. It is, therefore, poss to build up components at the site by use c truck crane. This corner column should be divi into two pieces when helicopters are used as tra portation.

Building components of outer walls are usu built up after completion of steel frame erecti It is, therefore, necessary to perform heavy h work from a position away from the build component, if the hoist work is restricted due site conditions. The hoist work condition, types of hoist and the maximum weight of bui ing component are shown in Table 5. From t table it may be concluded that the maxim weight of one outer wall component unit should less than 1 ton if truck cranes are to be used hoist work.

Table 5 TRANSPORTING PRECAST CONCRETE PANEL AND HOIST WORK CONDITIONS

Transport Conditions	Transport Means	Hoist Work Conditions / Erecting Equipment	Erection from one direction	Erection from two directions	Erection from three directions	Erection from four directions
						
Site has road	4 ton truck	5 ton truck crane	×	×	1	25
		5 ton trunk crane Jib crane	1	1		
Site has no road	Helicopter 2.5 ton	Gin pole derrick Jib crane	1	1	1	1
		Gin pole derrick	25	25	25	25

1 Weight limit is 1 ton

25 Weight limit is 2.5 tons

× It is impossible to erect precast concrete panel in the rear.

The component size was limited to the same size as usual components so that no problems would occur during transportation.

5.2 Outer Wall Design

The outer wall of the station building consists of curtain walls made of precast concrete panels. These panels are heavier than the usual materials, however, it is not difficult to preserve the required building quality at a comparatively economical price. It was determined that a curtain wall made of precast concrete panels was most suitable and practical.

At one time, it was considered to use an outer wall made of metals. However, this idea was not found applicable in a mountainous country like Japan, for fear that interference with radio waves would occur because of the short distance between radio relay stations.

5.2.1 Panel Weight and Shape

It is necessary to limit the weight of a single panel to less than 1 ton, due to the heavy hoist work conditions described in Section 5.1.2. Efforts were made to make the light weight panel, to make panel larger in size within the allowable weight limit. Consequently, the number of components were reduced, thus decreasing the field work.

The standard panel size is 4.3 meters high and 1.2 meters wide. Artificial light weight aggregates are used. The weight of one panel is approximately 950 kg.

5.2.2 Concrete Mix Proportions

Regarding weather conditions on a mountain side or top, severe conditions should be taken into account, particularly the extremely low temperature and heavy snow during the winter. Concrete mix proportions were selected to preserve light aggregate concrete durability and resistance against freezing, when used for the precast concrete panel.

(1) Artificial light aggregates were used for both coarse aggregates and fine aggregates. To increase concrete strength, workability and durability, a certain amount of natural sand was added to the fine aggregates within the weight limit of a precast concrete panel.

(2) For obtaining concrete strength and resistance against freezing, a lesser amount of water in light weight concrete is preferable, as compared to the normal weight concrete. Therefore, 50% ~

65% water cement ratios were selected, according to the damage anticipated due to freezing at each zone.

(3) Air-entrained agent is usually used to increase the concrete workability, however it also works to increase durability against freezing and melting. In this case, 5%～6% air-entrained agent was selected for light weight concrete.

5.2.3 Outer Wall Composition

(1) The expected relative story displacement would be within the range between 1/200 and 1/300, when divided by the story height (approximately between 20 mm and 5 mm) if the station building is subjected to 0.3 G input ground acceleration. Therefore, steel fasteners on precast concrete panels were designed to follow a 20 mm relative story displacement.

(2) In order to protect the inner wall surface from moisture due to the heat bridge effect, doubly folded walls are constructed by fixing insulation material on the precast concrete panel vertical rib inside the wall at the site. (Refer to Fig. 6.)

(3) Chloroprene rubber gaskets were used at the corner and edge of each precast concrete panel to preserve watertightness. Since external scaffolding and caulking at the site were not used in this construction method, it helps to save much site work and to obtain construction reliability.

If water should leak into the panel through the gaskets, the water can safely be drained out through drain pipes installed in the panel.

Gasket watertightness was examined by water tight experiments using a full scale panel. As a result of the experiments, it was found that a small amount of water may leak through the horizontal gasket and crossing gasket. However, water leaked through the double folded panel was drained out through drain pipes and no water was found to leak inside the room. This confirms that watertightness is obtained, as initially expected.

(4) At the corner of outer walls L-shaped precast concrete panels were installed, such that errors in setting the panels in the proper position would be dealt with. (Refer to Fig. 7.)

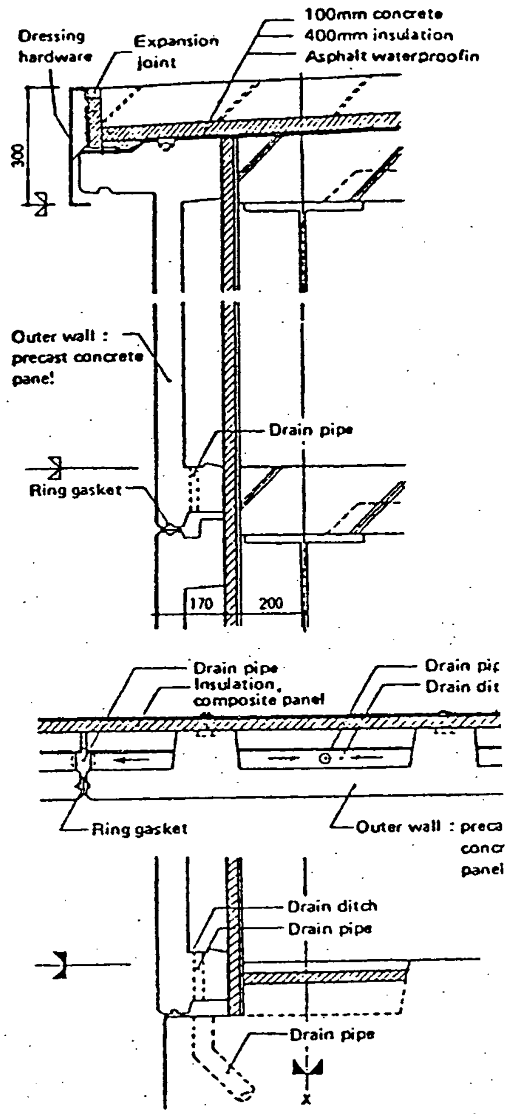


Fig.6—Double folded outer wall detail.

5.3 Floor and Roof Design

5.3.1 Floor Slab

It is the most economical method to constru floor slabs, if they are cast-in-place reinforce concrete structures. Since floor slabs are hor zontal members, concrete can be easily cast on th site. It would hardly be anticipated that the sla construction grade would cause troubles. To sav on site work, deck plates were used as permanen form to construct cast-in-place reinforced concret slabs.

Table 6 MAIN DESIGN LOADS

	*1	*2	*3	*4
Calculating floor strength	1000	300	1250	1250
Calculating beam strength	1000	300	900	850
Calculating rigid frame strength	1000	180	800	700
Calculating seismic strength	500	80	500	400

*1 Roof
*2 Office
*3 Exchange equipment room
*4 Power room

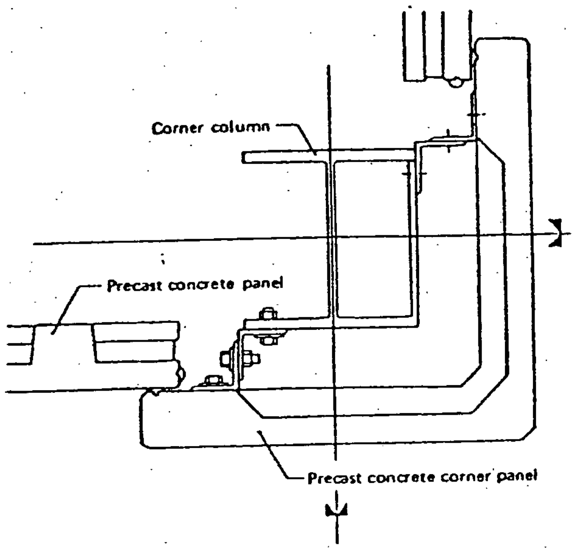


Fig.7–Precast corner concrete panel detail.

5.3.2 Roof

Since radio relay stations were constructed on a mountain side or top, the conventional method of constructing parapets along the roof area caused some leak trouble. This was partly due to fallen leaves, which blocked the roof drain, causing the vertical asphalt waterproofing to freeze. By examining the trouble, grading roof (hyperbolic paraboloidal roof with maximum grading of 1/25) was installed to drain rainfall from the roof directly without roof drains.

Asphalt waterproofing was used for the roof because of its reliability. Asphalt waterproofing was partly glued to the roof slab to avoid damage to the proofing caused by concrete roof slab deformation. This roofing method enables air to move through the lower space under the roofing. Insulation board was attached to the upper roofing surface to decrease heat effect on the roofing.

6 Structural Design

6.1 Design Conditions

Design live loads and external loads for the radio relay station are shown in Tables 6 and 7, respectively. Three meter snow load was assumed for designing the roof floor, as shown in Table 7.

Table 7 EXTERNAL FORCES

	Content
Earthquake	Damping coefficient: 2% Input acceleration: 300 gal
Wind	Wind velocity pressure: $q = 120\sqrt[4]{h}$ and more than 300 kg/m²

6.2 Structural System Outline

An outline of the prefabricated station structural system is as follows:

(1) Structural frames:

Braced steel frame structure. Both rolled and built up wide flanges (H frames) were used for such structural members as beams and columns (in which built up wide flanges were used only for corner columns). Mainly pin connections were used for connecting columns to beams, however rigid connections also were used partly.

At all steel frame connections, bolted joints were adopted to simplify on site work.

(2) Earthquake resistant element:

Several types of braces were examined in terms of structural performance, cost and reliability of construction. As a result of examination, it was decided to use K-shaped braces as earthquake resistant elements, which were arranged along perimeter frames, on the grounds that these braces were superior in structural performance, planning and cost of the station building. Steel pipes were used for bracing members, on the ground that they were isotropic and resistant to buckling.

(3) Floor and foundations:

Cast-in-place reinforced concrete construction was selected for floors and foundations, considering economic superiority. The structural members arrangement for roof floor and second floor are shown in Fig. 8.

6.3 Structural Analysis

6.3.1 Dynamic Analysis

Dynamic analysis was carried out to confirm the earthquake resistance of the radio relay station building. This structural system may be special in that it consists of a smaller station building on which a relatively larger steel tower stands.

In the dynamic analysis, the station building with steel tower was idealized as a space frame. Structural stiffness and natural periods were obtained by means of a stress analysis computer program, FRAP-GEN, which has been developed as a series of scientific computer program library named DEMOS-E by NTT. Earthquake responses of the station building were obtained by means of a model analysis based upon the previous eigenvalues of the structural model. Input response spectrum of acceleration used in the analysis is shown in Fig. 9. Considering the steel tower effect on the total vibration system, 2% damping coefficient was assumed in the analysis. It was decided that the main structure should remain elastic for 0.3 G input ground acceleration.

Vibration modes and natural periods are shown in Fig. 10. Figure 11 shows shear coefficients. Based upon these results, the design shear coefficients were chosen as 0.84 at the base and 1.31 at the top of the steel tower.

6.3.2 Stress Analysis and Member Design

Based upon the external force, reported in Section 6.3.1, as shown in Tables 6 and 7, stress analysis was carried out using FRAP-GEN. The external force directions were assumed to be inclined 0 degree and 45 degrees to the axis of the station building. The bases of columns were assumed to be pin support. Design stresses are shown in Fig. 12.

Structural members were designed for the

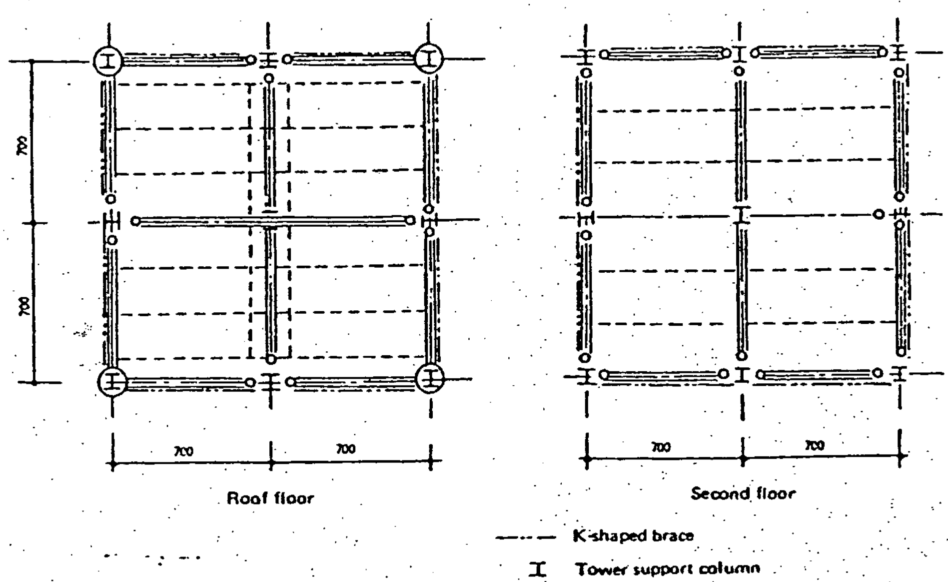


Fig.8–Support members arrangement. (D4 type)

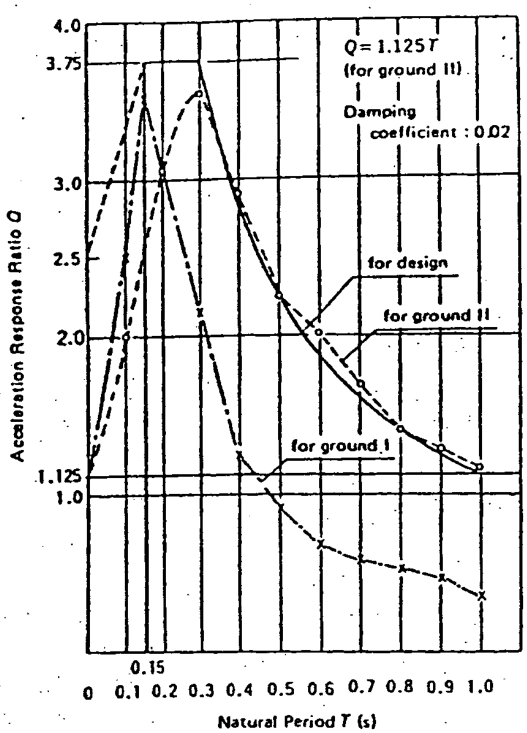


Fig.9–Acceleration response spectrum for design.

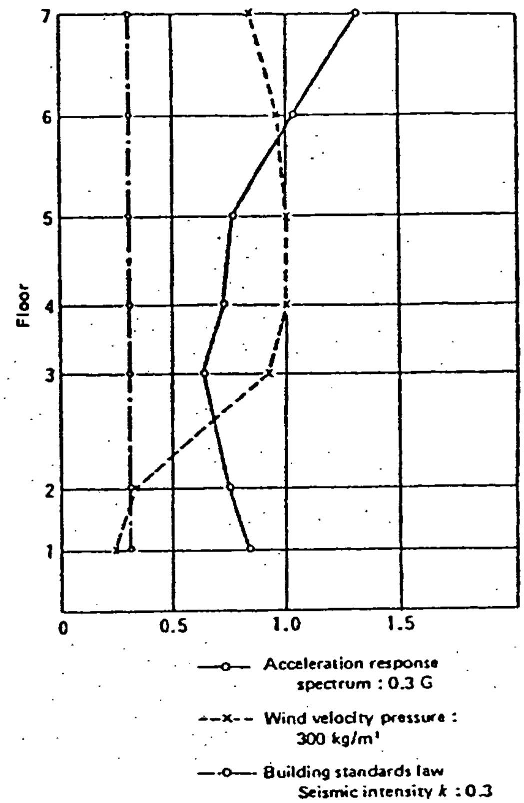


Fig.11–Shear coefficient. (S.C)

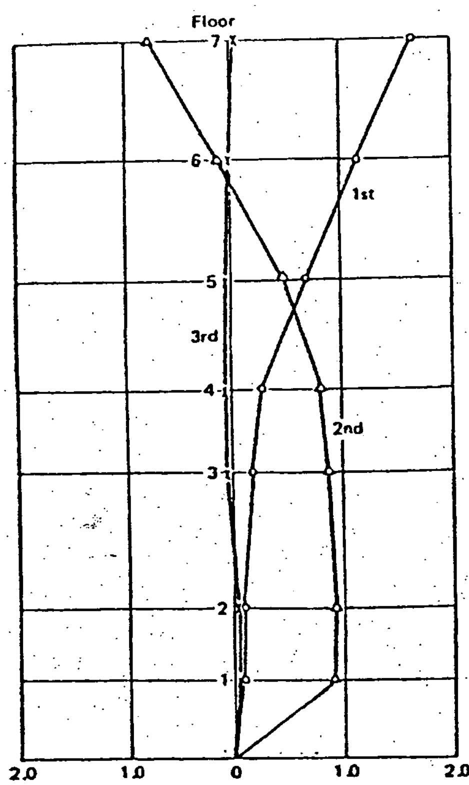


Fig.10–Mode.

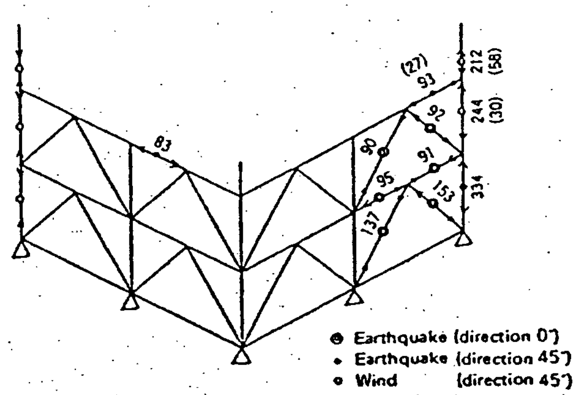


Fig.12–Design member force.

maximum stresses of external forces, including the change in force direction.

7 Heating, Ventilating and Air-conditioning System Design

7.1 Air-conditioning System of Radio Equipment Room

Usual ventilation system has been adopted for the air-conditioning system in the equipment room. However, in this prefabricated station building, air cooled small package air-conditioner system was proposed to save manpower at the site, to increase temperature and humidity control ability, and to obtain reliability and economization. In this proposed system, the number of small package air-conditioners should be increased in response to an increase in heat load. The number of air cooled small package air-conditioners at the final stage reaches two for a two story station building and one for a single story station building, with one back-up air-conditioner to preserve reliability.

Since much heat radiation is expected at the equipment room in a radio relay station, air-conditioning is sometimes necessary, even in winter. Genrally, it is not possible to drive an air cooled air-conditioner based upon refrigerating cycle, using a usual compressor during winter. In order to overcome this, a new natural cycle mechanism was installed, which is intended to make use of cold heat source that is derived from the diffence in temperature between outdoors and indoors, thus enabling using an air-conditioner when the outdoor temperature is low. This device enables savings on electricity consumption by using the cold heat source during winter.

7.2 Power Room Ventilation

Air is necessary in the power room, particularly when the air cooled spare engine is operating. It is necessary to ventilate the room air after heat transfer. It is also necessary to ventilate organic gas after charging batteries. These factors indicated that a power room ventilation system should be provided, as in the case of a usual radio station building.

7.3 Sanitary Equipment and Electric Equipment

Exposed pipes for sanitary equipment and electric equipment were installed because dry c struction method was used for the prefabrica station building.

8 Evaluation

Compact layout of prefabricated radio re station was successfully obtained by locating plan within the area of steel tower legs. Reduct in total floor area was also obtained (by 15% two story station building, by 22% for single st station building) in comparison with the case a usual standard station building, thus yield economic superority. The prefabricated constr tion system was compared in detail with the us cast-in-place construction system. For the t story station building, advantages are as follo

(1) Six month construction period, that two months shorter than a usual construct period. This enables completing all construct work, including steel tower construction, bef the heavy snow season, if the work is started early spring.

(2) The amount of transported construct materials is approximately 1,330 tons in weig reducing to 52% of the requirements of the us construction method.

(3) The amount of site work is reduced to 5 of the usual construction method. Therefore, prefabricated construction method can prese merits as initially expected. (Refer to Table For a single story station building, the effe described in this sub-section can also be obtain

9 Concluding Remarks

Utilization of a prefabricated station build was proposed for constructing radio relay stat buildings all over Japan, except in special zo This proposal was made mainly for dealing w problems arising from severe conditions due geography and weather. Two categories of us standard station buildings were taken into acco in the proposal. Brief explanations of the p fabricated station buildings, together with th special features, are as follows:

(1) The combination of steel tower with s tion building was determined such that the st

Table 8 DESIGN AIMS AND ATTAINMENT PROBABILITY

Item		Prefabrication System		Conventional Standardized System (Reference)
		Design Aims	Probability of Attainment	
Construction period		6 months	6 months	8 months
Cost	Building	100% conventional standardized system	100% *	100%
	Equipment	100% conventional standardized system	90%	100%
Amount of materials transported		65% (1,500 ton)	52% (1,330 ton)	100% (2,540 ton)
Manpower in the site		60%	50%	100%

* Estimation in constructing 40 buildings per year

tower is erected on the station building. This combination does not require a large construction area at the site, preserves freedom in selecting the station building and the tower combination within a certain extent. The steel tower used in the proposal was the usual standard steel tower.

(2) Structural frames of the station building were made of steel with steel braces used as earthquake resistsant elements. Stress analysis and structural design were made by assuming that the steel tower and the station building can be dealt with as one structure. The reason for using steel frames is that this eases transporting and erecting materials at the site.

(3) The station building layout was determined such that building layout plan could be made compactly within the tower leg area.

(4) Size and weight of structural components were determined by considering their transporting conditions and method of erection. Regarding transporting conditions, 4 ton trucks and helicopters (whose transport capacity is 2.5 tons) were also considered.

(5) Curtain walls made of precast concrete panels used for outer walls, which were relatively cheap in cost and reliable in building performance. Efforts were made to decrease the weight of panels to build up easily at the site. Chloroprene rubber gaskets were used at the corner and edge of each precast concrete panel to preserve watertightness. Double folded outer walls were used to protect its inner surface from moisture due to heat bridge effect. Insulation boards were glued to the inside vertical rib of precast concrete panel.

(6) Cast-in-place reinforced concrete was selected for floors, considering its construction reliability and cost superiority.

(7) Grading roof was used to drain rainfall smoothly through the roof directly without roof drains, thus avoiding leak troubles. Asphalt waterproofing was glued partly to the roof slab in order to avoid damage to water proofing due to concrete slab deformation.

(8) Air cooled small package air-conditioners were used for the equipment room in order to save on site work, to increase control ability and to obtain economization, when compared with a usual ventilation system. This system requires less space in the equipment room, compared to usual ventilation, thus enabling saving total floor areas in the station building.

It was confirmed, by performing experiments, that the space obtained by assembling structural components would be available for use as initially expected. It was found that construction period, amount of site work and transporting materials could be reduced, in comparison with usual construction system values. This proposed system was found to perform as initially expected.

Acknowledgement

The authors thank Mr. Ono, Director of Building Engineering Bureau in NTT, and the personnel concerned in NTT for advice and help on utilization of a prefabricated station.

The authors also thank staff members of Izumi Soken Engineering Co. Ltd. and of Kozo Keikaku Engineering Co. Ltd. for their assistance in obtaining design information.